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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003901872 for a patent by POLYMERS AUSTRALIA PTY LTD as filed on 31 March 2003.



WITNESS my hand this
Ninth day of April 2004

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Polymers Australia Pty Ltd

A U S T R A L I A

Patents Act 1990

PROVISIONAL SPECIFICATION

for the invention entitled:

"Fire Performance Cable"

The invention is described in the following statement:

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FIRE PERFORMANCE CABLE

The present invention relates to fire performance electrical cables, to their manufacture and to their use.

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Electrical cables typically include a central conductor surrounded by an insulating layer. When exposed to fire the material from which the insulating layer is formed undergoes thermal decomposition. The product of this decomposition tends to be a fragile and brittle char that is susceptible to cracking and dislodgment thereby exposing the conductor.

10 Water being used to extinguish the fire may come into direct contact with the conductor causing electrical shorting and power failure. This is a particular problem for cables in emergency supply circuits, and the like, which are required to continue functioning for as long as possible in the case of a fire.

15 A variety of attempts have been made to provide modified insulation for cables where the insulation forms a physically robust and coherent char layer after exposure to fire. The intention is that this layer remains in place after a fire thereby maintaining insulating function. The problems mentioned above can still occur however as the char layer tends to be substantially porous and/or includes significant cracks. Thus, even though the layer is
20 macroscopically intact, water is able to permeate the char layer resulting in a short circuit or failure of the insulation.

The present invention seeks to provide a cable which has an insulating layer that is retained in place even after exposure to fire thereby maintaining its insulating function, and which
25 includes means for minimising or preventing contact of the conductor with water which may be present in the surroundings.

Accordingly, the present invention provides a fire performance electrical cable comprising:
a conductor;

30 an insulating layer the insulating properties of which are retained throughout exposure at an elevated temperature and cooling; and

a glaze-forming layer comprising a component which, after exposure at the elevated temperature and cooling, forms a glaze layer which is substantially impervious to water.

As will be described, invariably the glaze-forming layer is provided adjacent and in direct physical contact with the insulating layer. It has been found that the glaze-forming layer may in fact enhance the structural integrity and strength of the insulating layer. It has also been found that the glaze formed after exposure to elevated temperatures may enhance the structural integrity and strength of the char layer formed from the insulating layer. These effects are believed to be due to interaction between the layers at their interface.

Central to the present invention is the use of a distinct glaze-forming layer to form a glaze layer which acts as a barrier to any water which may be present in the surroundings. This glaze layer prevents access of water to the conductor by being substantially impervious to water. The glaze layer may include minor defects (such as discontinuities, pores and cracks) but these are preferably at a level such that any water which is able to pass through the glaze layer is negligible. Preferably, the glaze layer is coherent and continuous such that no water at all is able to pass through it.

The glaze-forming layer includes a component which is capable of forming a water impervious layer (glaze) after heating at the kind of elevated temperatures encountered in a fire followed by cooling. Cooling may take place naturally or as a result of specific measures taken to extinguish the fire, such as water spraying. One or more glaze-forming components may be employed. In general terms, the glaze layer may be formed by softening/melting and coalescence of glaze-forming component(s) to form a continuous and coherent glaze. The glaze solidifies on cooling. It follows from this explanation that the glaze-forming component(s) must soften/melt at elevated temperature such that individual component particles may amalgamate to form the glaze layer. Ideally, the glaze-forming components form a liquid which has a suitable viscosity and which can flow (to a limited extent) in order to achieve formation of the glaze layer. Although not essential, chemical reaction between the glaze-forming components may be responsible at least in part for formation of the glaze layer. Other additives which may be present, such

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as refractory extenders etc, may also contribute to glaze formation by either of these proposed mechanisms.

For obvious reasons, the effect of the invention would not be observed if the glaze-forming composition consists of components which do not undergo the necessary coalescence and/or reaction at the kind of temperatures associated with a fire situation. It is desirable that the glaze-forming layer includes one or more glaze-forming components which are capable of forming a suitable glaze at temperatures as low as 500°C. As copper melts at 1080°C, it is unnecessary that the glaze-forming composition will include glaze-forming components which are "activated" at temperatures higher than this.

As noted, it is desirable that the glaze-forming component forms a liquid at the kind of temperatures encountered in a fire situation. At these temperatures the viscosity of the liquid component may be important. If the viscosity is too low, the liquid is likely to flow too readily and this may cause depletion of glaze in certain areas and accumulation in others. This can lead to defect formation. If the glaze conducts electricity and is of low viscosity, it may also cause electrical conductivity problems. For instance, when the glaze-forming layer is provided over an insulating layer the glaze formed may flow through any pores and/or cracks present in the insulating (char) layer establishing a conductive path from the conductor to the external surface of the insulating layer. On the other hand, if the liquid is too viscous and has a high surface tension at elevated temperatures, formation of a coherent and continuous layer of glaze that has suitable wetting and adherent properties may be inhibited. When provided over an insulating layer, it is desirable that the glaze wets and adheres well to the char layer formed at elevated temperature. This may be important to achieving the strength benefit mentioned earlier. The liquid glaze preferably has low electrical conductivity, a low surface tension and moderately high viscosity at elevated temperatures and the glaze-forming component may be selected accordingly.

There may be advantages associated with using a mixture of two or more glaze-forming components. For instance, it has been observed that a relatively low melting point component can be absorbed into an underlying insulating layer at high temperature. This

effect can be reduced by mixing the relatively low melting component with a glaze-forming component which melts at a higher temperature. The use of mixtures of glaze-forming component may also increase the temperature range over which a suitable glaze layer may be formed.

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Bearing in mind the various factors described above, the glaze-forming component may be selected from:

- (a) Combinations of two or more materials that react/combine to form a molten glass at elevated temperature. Some typical examples of such combinations include
10 silicates (such as mica and feldspar), phosphates, borates and/or their precursors mixed with alkali oxides, alkaline earth oxides, certain transition metal oxides (e.g. zinc oxide) and/or their precursors. By "precursors" is meant any compound which yields the material (in compound form) on heating.
- (b) Glasses, or mixtures of glasses, that soften/melt at elevated temperature. It is
15 desirable that the glass has low electrical conductivity at elevated temperatures. The glass therefore preferably has low alkali metal content.
- (c) Combinations of one or more of (a) and (b).
- (d) Combinations of (c) with up to 75% of a refractory filler such as, but not limited to, alumina, zirconia, rutile, magnesia and lime.

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It is possible, but by no means essential, that the glaze-forming layer includes additional components and this will depend upon the way in which the layer is to be provided as part of an overall cable structure. In one embodiment the glaze-forming layer consists of the component which is capable of forming the glaze. In this embodiment the component may
25 be applied directly to the surface of the conductor (and covered by the insulating layer) and/or to a layer covering the conductor, typically the insulating layer, of the cable being manufactured.

In this case, the component may be applied by an electrostatic deposition technique in
30 which a substrate to be coated (i.e. the conductor or other cable layer) is earthed and the component electrostatically charged. Electrostatic forces cause the component to be

attracted to and lodged on the surface of the substrate. In practice, application of the glaze-forming layer takes place as part of a continuous process for formation of a finished cable. If the glaze-forming layer contains a resin, high output IR lamps or other sources of heating may be used to melt the resin so that it flows forming a smooth coating. This coating can subsequently be crosslinked either by continuing the heat application, or by UV cure systems. This can also be done in the course of applying extruded layers to the cable in a continuous operation.

Alternatively, this embodiment may be achieved by use of a fibrous mat/sheet of glaze-forming component. In this case, the glaze-forming component is applied by wrapping the mat/sheet around the conductor or the insulating layer of the cable. This process has the disadvantage that it tends to be time-consuming and laborious. The fibre density making up the mat/sheet should be such that individual fibres may soften/melt and/or react to form a continuous and coherent layer of glaze.

In the embodiments described, the amount and distribution of glaze-forming component is such as to allow a layer of glaze to be formed which is substantially impervious to water. The particle size (or fibre diameter as the case may be) of the glaze-forming component will influence this. When particles of glaze-forming component are used, the average particle size is 200 microns or less, preferably 50 microns or less and, more preferably, 20 microns or less. These dimensions also apply to the average diameter of fibres typically making up a mat/sheet of glaze-forming component.

In a separate embodiment, the glaze-forming composition may comprise a glaze-forming component homogeneously dispersed in a suitable carrier. The composition may be formed by known blending techniques. The carrier is intended to enable application of the composition in an essentially uniform layer. Suitable application techniques are described below. It is an important characteristic of the carrier that it has the capacity to be loaded with a sufficient amount of the glaze-forming component such that a suitable glaze may be formed at elevated temperature, whilst retaining suitable processability to allow the composition to be applied as a layer of a cable. Thus, the carrier must have satisfactory

rheological properties. Desirably, the carrier also has the ability to wet both the components dispersed in it and the substrate to which the glaze-forming composition is to be applied, and develops high strength when cooled or cured (depending upon the nature of the carrier). It is also important that the carrier does not include anything which interferes with glaze formation at elevated temperature. Ideally, the carrier is one which thermally decomposes at this temperature leaving no residue. The presence of residue may lead to discontinuities and defects in the glaze layer and can cause conductivity problems if the residue is electrically conductive. It is also preferable that heating or decomposition of the carrier does not lead to generation of excessive amounts of gaseous by-products. Furthermore, the carrier preferably decomposes at temperatures below that at which formation of the glaze commences.

The carrier may be a thermoplastic polymer which is conventionally used to provide a layer of a cable, such as a sheathing layer. In this case the carrier is loaded with a suitable amount of glaze-forming component and extruded in a conventional manner to form a glaze-forming layer. No curing of the layer is required to fix it since this may be achieved simply by cooling. It is preferred that the carrier used sets to provide a non-tacky layer as quickly as possible since the glaze-forming layer is generally applied as part of a continuous process involving application (by extrusion normally) of an additional layer over the glaze-forming layer. The application of this particular methodology is less useful if the carrier polymer does not burn out cleanly at elevated temperature.

With rapid curing in mind, it is preferred that the carrier may be heat-cured or radiation-cured. Thus, the carrier component of the glaze-forming composition may be selected from homopolymers and copolymers of alkyl acrylates, alkyl methacrylates, low molecular weight polyurethanes that are functionalised with acrylic double bonds (referred as urethane acrylates) and silicone resins which can be cured by UV radiation followed by atmospheric moisture as secondary cure system. Another class of radiation curable resins suitable for use as the carrier component is polyesters with acrylate functionalities.

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The rheology of the glaze-forming composition should be such that it enables the composition to be extruded by conventional techniques to form a smooth and continuous layer. The viscosity of the carrier used and the loading of glaze-forming and, possibly additional, components will be significant here. Purely by way of illustration, the carrier
5 resin may have a viscosity in the range of 15-1500 cP at 25°C, more preferably from 30-400 cP at 25°C.

As a further alternative, the glaze-forming component may be provided on the outer surface of the cable by contacting the latter with a slurry of glaze-forming component
10 homogeneously dispersed in a suitable medium. The slurry may be applied by dipping or brushing. Preferably, to achieve rapid fixing of the glaze-forming layer, the medium in which the glaze-forming component is dispersed is quick-drying or volatile. The slurry can also contain a geopolymer composition which usually consists of an aluminosilicate dissolved in an alkali metal silicate solution, such as potassium silicate. On heating, the
15 geopolymer forms a glass. Furthermore, it is also possible to make use of sol-gel technology to coat a surface layer of glass-forming composition in this embodiment.

The weight ratio of the glaze-forming component to carrier/medium is usually is within the range of 0.9:1 to 1.2:1. It is important that this ratio is kept as high as possible to facilitate
20 the formation of a continuous glaze layer.

Once applied and suitably fixed, the glaze-forming layer is usually covered by at least one additional layer of the cable. This layer may be applied by extrusion downstream of the site at which application of the glaze-forming component takes place. For instance, the
25 glaze-forming layer may be provided on an insulating layer in direct contact with the conductor and a layer of sheathing polymer extruded over the glaze-forming layer immediately after application thereof. Provision of a layer over the glaze-forming layer may also help to fix the latter in position. A cut-resistant layer may also be provided between the glaze-forming layer and the sheathing layer. Such a cut-resistant layer may be
30 extruded over the glaze-forming layer and the sheathing layer then extruded over the cut-resistant layer.

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Depending on the fraction of glaze-forming component in the coating composition, the glaze-forming layer usually has a thickness of 500 microns or less, preferably 250 microns or less and, more preferably, 100 microns or less. For economy, it is preferred to use the minimum amount (and thus thickness) of glaze-forming component in order to achieve the desired result, as described above. Typically, the thickness of the glaze-forming layer is only a fraction of the thickness of the insulating layer which is used. For instance, the thickness of the glaze-forming layer is generally 50% or less than the thickness of the insulating layer. In practice, the insulating layer may be say 0.8 mm and the glaze-forming layer 0.4 mm in thickness. One skilled in the art may of course modify these relative thicknesses in order to optimise the effect of each layer.

Suitable glaze-forming components, carriers and mediums for use in practice of the present invention are commercially available.

The present invention also provides a process of the manufacture of an electrical cable by the techniques described herein.

The insulating layer may be formed from a variety of compositions. Preferably, the insulating layer is formed from a composition which forms a ceramic when exposed to elevated temperature, i.e. the kind of temperature encountered in a fire situation. The ceramic forming composition may be non-silicone polymer-based, silicone polymer-based or include a base composition comprising a blend of silicone and non-silicone polymers. The compositions may include a variety of inorganic components capable of yielding a ceramic by reaction at elevated temperature. The compositions may also contain additional functional additives such as flame retardants etc. Useful compositions and their preparation are well-known in the art. Useful compositions and their preparation are also described in our co-pending Australian provisional patent application nos. 20029500536, 2002952136 and 2002952139, the content of which in relation to such compositions is hereby incorporated by reference.

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The present invention also provides an electrical cable comprising a conductor, an insulating layer as described herein and a glaze-forming layer as described herein. The cable may be a single or multi-core cable. The glaze-forming layer may be provided between the insulating layer and conductor with the intention that the resultant glaze layer will prevent contact between the conductor and any water which may have permeated the insulating layer. Alternatively, or additionally, the glaze-forming layer may be provided external to the insulating layer so that the resultant glaze will prevent water contacting the (permeable) insulating layer. Typically, the glaze-forming layer will be provided external to the insulating layer. The cable will usually include at least one additional functional layer, such as cut-resistant and outer sheathing layers. In one embodiment, the insulating layer is provided directly over the conductor with the glaze-forming layer provided directly over the insulating layer. A sheathing layer is provided over the glaze-forming layer to provide a finished cable. In an alternative embodiment the cable further includes a cut-resistant layer between the glaze-forming and sheathing layers. In practice the glaze-forming layer will not be provided as the outer layer of a finished cable.

Embodiments of the present invention are illustrated in the following non-limiting examples.

In each of the following examples the insulating layer is of the type described above.

Example 1

In this Example, the glaze-forming composition was made by mixing thoroughly 46 parts by weight of a commercially available UV curable acrylic resin (TRA-coat 15C) having a viscosity of 1175 cPs at 25°C with 10 parts by weight of a fine muscovite mica having a mean particle size of approximately 40 µm and 44 parts by weight of glass frit "A" having a softening point of 525°C (and a composition given in Table 1 below) to produce a homogeneous mixture. The glaze-forming composition was then applied over an insulating layer of a cable sample and also over a sheet of insulating material of 25 mm x 15 mm x 2 mm dimensions using a soft brush. UV curing of the glaze-forming layer was performed

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using an F-600 lamp (120 W/cm, 365 nm) in air at a conveyor speed of 2 m/min. Samples were cured after one pass through the irradiation unit. The thickness of the glaze-forming layer was in the range of 100-600 microns. The coated samples were then fired in a muffle furnace at 1000°C for 30 minutes. On visual inspection the fired samples had no major defects/cracks. The glaze-forming layer was found to have formed a continuous ceramic glaze on the insulating layer upon firing. This glaze layer was impervious to water as revealed by the retention of a water droplet on the glaze for over one minute without permeating into the insulating layer underneath.

10 Example 2

Replacing 9 – 23 parts by weight of glass frit in the glaze-forming composition described above with zinc borate or boric oxide further improved the imperviousness of the glaze layer to water.

15

Example 3

In this Example, the glaze-forming composition was made by mixing thoroughly 40 parts by weight of an aqueous solution of poly(vinyl alcohol) containing 90% water with 30 parts by weight of glass frit "A" having a softening point of 525°C and 30 parts by weight of glass frit "B" having a softening point of 800°C and a composition given in Table 1 below to produce a homogenous mixture. The glaze-forming composition was then applied over the insulating layer of a cable sample using a soft brush. The composition was allowed to dry in air for two hours. The thickness of the glaze-forming layer was in the range of 150-300 microns. The coated sample was then fired in a muffle furnace at 1000°C for 30 minutes. On visual inspection the fired sample had no major defects/cracks. The glaze-forming layer formed a continuous ceramic glaze on the insulating layer upon firing. This glaze layer was impervious to water as revealed by the retention of a water droplet on the glaze for over one minute without permeating into the insulating layer underneath.

Example 4

Replacing 10 parts by weight of glass frit B in the glaze-forming composition described above with a fine muscovite mica having a mean particle size of approximately 40 μm resulted in a glaze layer that is uniform and impervious to water.

Example 5

In this Example, the glaze-forming composition consisted of glass frit "C" having a softening point of 525°C. The glass frit powder was applied over the insulating layer of cable samples by pulling the cables through a vibrating bed of glass frit powder. This application method may not be practical on commercial scale but the end result is essentially the same as would be achieved by the electrostatic deposition method described above. Coated cable samples and non-coated, otherwise identical, cable samples were then fired in a gas fired furnace to 1050°C in 2 hours followed by water spraying for 3 minutes according to the Australian standard AS3013 involving water sprayed at a distance of 2.5 m to 3.0 m at a rate of 12.5 l/min. It was found that the cables coated in accordance with the present invention showed much superior water resistance than the comparison cable without the glaze-forming layer. The latter in fact shorted within 1 minute while the cable with the glaze-forming lasted the entire 3 minute period of water spraying. This is believed to clearly demonstrate the effectiveness of the glaze-forming layer in reducing the permeation of water into the insulating layer after exposure to high temperature.

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Table 1. Composition of glass frits given in weight percent of constituent oxides

Glass Frit	SiO ₂	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	Al ₂ O ₃	CaO	Fe ₂ O ₃	ZnO	V ₂ O ₅	Other
A	37.7	14.6	10.6	16.0	1.3	1.2	1.0	3.0	-	-	14.5
B	39.2	2.9	2.2	-	-	5.5	5.3	-	36.2	-	8.7
C	13.5	18.2	10.8	19.3	1.8	-	-	-	-	8.7	7.7

Dated this 31st day of March 20035 **Polymers Australia Pty Ltd**

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